**Final Report**

# A Pilot's Landing Assistance System
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**Principal Investigator: Ramesh Jain**

Visual Computing Laboratory
University of California, San Diego
La Jolla, CA 92093-0407
Phone: (619) 534-8639
Fax: (619) 534-2486

Many complex systems deal with information from multiple sources. A system guiding a pilot should be able to dynamically assimilate information from on board sensors and communication . An autonomous robot, like its human counterpart, needs to interact with its environment using multiple sensors and actuators. A system collecting multi-modal information from information servers for presentation to the user should assimilate multiple sources of information. One common feature in all these systems, varying in degrees of autonomy, is the inherent dissimilarity of information sources. For example, in mobile robot applications input information includes point range data from sonar, depth maps from stereo and laser range-finder, motion and object location data from monocular camera, self position information from GPS and landmark recognition, symbolic scene information from a human operator, *a priori* information about objects in the scene from a map. All these information, though unregistered and unsynchronized, are complementary and describe a single environment and therefore all necessary for navigation tasks. This disparate nature of this information, however, makes it difficult to "combine" different information streams at the data level. Our research under this NASA funding developed a novel scheme to assimilate "relevant" information into an "environment" model and enabled the correct information to be made available at the right time.

Assimilation of information from disparate sources had not received enough attention . Much of the previous work in perception for complex systems has focused mainly on single or similar sensors. Our framework takes advantage of the strengths of these perception systems and handles disparate information, therefore overcomes the inherent weaknesses of such systems. In our approach, we focus on relevant information content in each information stream rather than the actual data itself. We use this to assimilate each stream directly into a single representation: the Environment Model. The synergy between disparate sources occurs through their common information content. We developed a formal framework for assimilation of information from disparate sources. This formal framework is based on a layered Environment Model to represent the state of an agent perception, cognition and action. The assimilation of information into the Environment Model in this framework is done in an exploratory fashion using expectations generated using the existing state information. Under the NASA funding, we demonstrated these concepts in two different contexts. In one context, we developed a Robo-cart that was equipped with different sensors and was remotely controlled using hand gestures. This cart was designed to mount disparate sensors so that we could perform experiments in information assimilation for mobile robotics. The second application developed a system that combined information from multiple cameras located in a courtyard. The signal from each camera was partially processed and then assimilated in an environment model. The environment model contained information about all objects in the environment and their

motion characteristics. A user could interact with the environment model to get information about any object and track the object using content-based interactivity. Many experiments were performed using this system. In summary, this NASA funding allowed us to refine the concepts and techniques in information assimilation. We developed the concept of the environment model further and used it in the contexts of mobile robots and Multiple Perspective Interactive Video.

Some publications that were result of at least a partial support of the NASA award are listed here. All these papers are available on our web site: vision.ucsd.edu.

**Relevant Publications:**


Arun Katkere, Saied Moezzi, Don Kuramura, Patrick Kelly, and Ramesh Jain. "Towards Video-Based Immersive Environments." ACM-Springer Multimedia Systems Journal: Special Issue on Multimedia and Multisensory Virtual Worlds, Spring 1997. A version available as Technical Report VCL-95-105.

Arun Katkere, Saied Moezzi, and Ramesh Jain. "Global Multi-Perspective Perception for Autonomous Mobile Robots." Workshop for Vision for Robots, IROS '95. PostScript version, 1995.

Patrick Kelly, Arun Katkere, Don Kuramura, Saied Moezzi, Shankar Chatterjee, and Ramesh Jain. "An Architecture for Multiple Perspective Interactive Video. " Technical Report VCL-95-103, Visual Computing Laboratory, University of California, San Diego, March 1995. A version was presented at ACM MM '95.

Arun Katkere, Saied Moezzi, and Ramesh Jain. "Global Multi-Perspective Perception for Autonomous Mobile Robots." Technical Report VCL-95-101, Visual Computing Laboratory, University of California, San Diego, March 1995.

Arun Katkere, Edward Hunter, Don Kuramura, Jennifer Schlenzig, Saied Moezzi, and Ramesh Jain. "ROBOGEST: Telepresence using Hand Gestures." Technical Report VCL-94-104, Visual Computing Laboratory, University of California, San Diego, December 1994.